(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
7 October 2010 (07.10.2010)

PCT

(10) International Publication Number
WO 2010/112958 A1

(51) International Patent Classification:
F01N 5/02 (2006.01) *H01L 35/22* (2006.01)
F01N 3/20 (2006.01) *H01L 35/30* (2006.01)
H01L 35/18 (2006.01)

(21) International Application Number:
PCT/IB2009/005596

(22) International Filing Date:
30 March 2009 (30.03.2009)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) **Title**: INTERNAL COMBUSTION ENGINE ARRANGEMENT COMPRISING A PARTICULATE FILTER AND A THERMOELECTRIC DEVICE

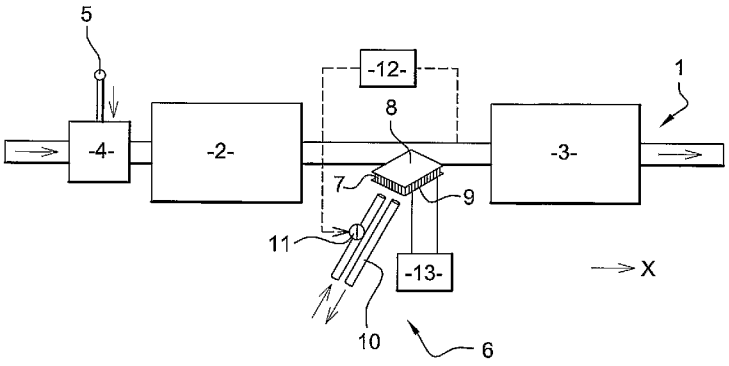

Fig. 1

(57) **Abstract**: The internal combustion engine arrangement comprises: - an exhaust line (1) capable of collecting exhaust gas from the internal combustion engine, said exhaust line including a particulate filter (2); - active regenerating means (4, 5) capable of generating heat during a regeneration period so as to promote oxidation of the particles retained in said filter (2); - a thermoelectric device (6) capable of producing electricity by Seebeck effect by the conversion of a heat flux between the hot exhaust gases flowing in the exhaust line (1) and a cold source, said thermoelectric device (6) being located downstream from said filter (2).

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INTERNAL COMBUSTION ENGINE ARRANGEMENT COMPRISING A PARTICULATE FILTER AND A THERMOELECTRIC DEVICE

Field of the invention

The present invention relates to an internal combustion engine arrangement comprising a particulate filter in the exhaust line, especially such an engine arrangement for an industrial vehicle.

Technological background

A conventional internal combustion engine arrangement comprises an exhaust line capable of collecting exhaust gases from the engine, for example through an exhaust manifold. Especially in the case of diesel engines, the exhaust gases may contain particles resulting from an incomplete combustion process in the engine. A particulate filter can therefore be provided in the exhaust line in order to retain these particles.

In order to regenerate the filter, a conventional solution is to use an additional heat or energy source to oxidize these particles. This oxidizing of the particles generates additional heat in the filter. As a result, known engines dissipate uselessly the energy content of the particles. Moreover, the energy consumed by the additional heat or energy source is not recovered, which makes the global energy balance even worse.

It therefore appears that, from several standpoints, there is room for improvement in engine arrangements regarding energy recovery.

Summary

It is an object of the present invention to provide an improved internal combustion engine arrangement, which can overcome the drawbacks encountered in conventional engine arrangements.

Another object of the present invention is to provide an internal combustion engine arrangement which can effectively increase the energy recovered in the exhaust line.

According to the invention, such an internal combustion engine arrangement comprises:

- an exhaust line capable of collecting exhaust gas from the internal combustion engine, said exhaust line including a particulate filter;

- active regenerating means capable of generating heat during a regeneration period so as to promote oxidation of the particles retained in said filter;

Additionally, according to the invention, said internal combustion engine arrangement further comprises a thermoelectric device capable of producing electricity by Seebeck effect by the conversion of a heat flux between the hot exhaust gases flowing in the exhaust line and a cold source, said thermoelectric device being located downstream from said filter.

Thus, in an arrangement according to the invention, the energy used to regenerate the filter and the energy contained in the particles both produce heat which is used by the thermoelectric device to generate electricity. In this way, at least part of this energy, which would otherwise be lost, is recovered and can be used for the operation of various elements of the vehicle, and/or can be stored in an energy storage component such as a battery.

According to a preferred implementation of the invention, the exhaust line includes a further after-treatment device, such as a selective catalytic reduction device (SCR), located downstream from said thermoelectric device. By providing a thermoelectric device upstream from a device such as a SCR, the invention ensures that said device is not damaged by too high temperatures resulting from the regeneration process. Indeed, the generation of electricity by means of the thermoelectric device leads to a decrease of the exhaust gases temperature. As a consequence, the thermoelectric device can protect the SCR during the regeneration period.

In concrete terms, the exhaust gases temperature downstream the particulate filter can be around 350 - 450°C when the filter is not being regenerated, depending on the engine operating conditions. On the other side, this temperature can increase up to 700°C during a regeneration period. The conversion in to electricity of the heat flux, due to the temperature difference between the hot exhaust gases flowing in the exhaust line and a cold source, by means of the thermoelectric device, can make this temperature decrease down to around 350 - 450°C, thereby preventing any damage to the SCR, or other after-treatment device.

In an implementation of the invention, the thermoelectric device can comprise thermoelectric elements made of a material or set of materials

having a maximum conversion efficiency between 500°C and 700°C, preferably between 500°C and 600°C. The "conversion efficiency" indicates the ability of a material or set of materials to generate electricity from a given heat flux through that material or set of materials. For a given material, this "conversion efficiency" depends on the temperature and has a maximum value in a certain temperature range. A good image of the conversion efficiency is given by the parameter $Z \times T_{average}$, where Z is the figure of merit of that material and $T_{average}$ the average temperature of the material. The figure of merit Z is itself known from the following formula:

$$Z = (Ec \times Sc^2) / Thc$$

where

Ec is the electric conductivity of the material

Sc is the Seebeck coefficient of the material

Thc is the thermal conductivity of the material, these parameters varying with the material temperature.

With this arrangement, the thermoelectric device is optimized for a range of temperatures that corresponds to the exhaust gases temperatures during a regeneration period.

The thermoelectric device may comprise thermoelectric elements made of at least one material pertaining to the following group: (p-Zn_4Sb_3, n-Mg_2Si), (p- and n-$CoSb_3$).

According to an embodiment of the invention, the internal combustion engine arrangement can comprise control means for controlling the heat flux through the thermoelectric elements, for example by controlling the flow and/or the temperature of the cold source, and/or control means for controlling the electrical current generated by the thermoelectric device. In both cases, this will influence the amount of heat which will be extracted from the exhaust gases through the thermoelectric device, and therefore, will influence the temperature drop for the exhaust gases across the thermoelectric device. Therefore, such control means can be used to control the temperature of the exhaust gases downstream from the thermoelectric device within a predetermined range. For example, when a SCR device (or another after-treatment device) is present, the temperature downstream from the thermoelectric device is preferably controlled so that it remains around the temperature leading to the best efficiency of said SCR and so that it does not exceed the upper limit temperature said SCR can undergo.

The internal combustion engine can further comprise deactivation means for deactivating the thermoelectric device outside a regeneration period. This arrangement can be used in case a SCR (or another after-treatment device) is present, and when the temperature downstream from the particulate filter is around the best temperature for said SCR. Indeed, in this case, decreasing the exhaust gases temperature would be detrimental to the SCR efficiency.

The cold source can be the engine cooling fluid, an auxiliary cooling fluid, and/or ambient air.

In an implementation of the invention, said active regenerating means comprise a dedicated fuel burner, a dedicated fuel injector, and/or a dedicated electric heater.

The thermoelectric device can be connected to a battery and / or to one or more vehicular component that are electrically operated.

Brief description of the drawings

The following detailed description of an embodiment of the invention is better understood when read in conjunction with the appended drawings, being understood, however, that the invention is not limited to the specific embodiment disclosed. In the drawing:

Figure 1 is a schematic drawing of an exhaust line of an internal combustion engine arrangement according to an embodiment of the invention;

Figure 2 is a chart showing the evolution of the temperature of the exhaust gases in the flowing direction, during a regeneration period, with an engine arrangement according to the prior art (dotted line) and with an engine arrangement according to the invention (full line).

Detailed description

An internal combustion engine typically comprises an engine block defining a plurality of cylinders. Intake air is carried towards the cylinders through an air intake line. The gases formed in each cylinder are carried towards the atmosphere by an exhaust line 1.

As shown in Figure 1, the exhaust line 1 comprises a particulate filter 2 and, in this example, downstream from said filter 2, an after-treatment

device which is a selective catalytic reduction device 3 (SCR) in the illustrated embodiment. An oxidation catalyst may be positioned in the exhaust line upstream of the particulate filter. An active regenerating means 4 is located in the exhaust line, upstream from the filter 2. This active regenerating means 4 can comprise a burner coupled to fuel injecting means 5. It can also be simply a fuel injector which injects fuel on the oxidation catalyst. It can also be an electric heater. Periodically, when needed (for example when the pressure difference upstream and downstream from said filter 2 exceeds a predetermined value), the active regenerating means 4 are activated. During such a regeneration period, the particles retained in the filter 2 are oxidized, and therefore the filter 2 is cleaned. This process is considered as active regeneration inasmuch as it uses the additional heat provided to the exhaust gases by the dedicated active regeneration means.

According to the invention, the exhaust line 1 is further provided with a thermoelectric device 6 capable of producing electricity by Seebeck effect. The thermoelectric device 6 is located in thermal contact with the exhaust line 1, downstream from the filter 2 and upstream from the SCR 3.

The thermoelectric device 6 comprises thermoelectric elements 7 arranged between a first wall 8 and a second wall 9. The first wall 8 is arranged directly or indirectly in thermal contact with the exhaust line 1, so as to achieve a good thermal exchange with the hot exhaust gases. The other side of the thermoelectric device, the second wall in this example, is arranged directly or indirectly in thermal contact with a cold source. In this embodiment, the cold source is a closed loop fluid cooling circuit. More precisely, the cold source is in this embodiment an engine coolant circuit or a derivation thereof 10 which carries the engine cooling fluid. In the illustrated embodiment, the coolant circuit 10 is equipped with a valve 11 the aperture of which is controlled by controlling means 12, depending for example on the on exhaust gases temperature, on engine operation parameters, and/or an the coolant temperature

Furthermore, the thermoelectric device 6 is connected to an electric circuit which may comprise a battery 13 as well as electric control means for controlling the electrical power in the circuit. In other embodiments (not shown), the thermoelectric device 6 can be connected to one or more vehicular components that are electrically operated.

The thermoelectric elements 6 comprise materials which can convert into electricity a heat flux between the hot exhaust gases flowing in the exhaust line 1 and the coolant flowing in the coolant circuit 10. In another embodiment – not shown – the cold source for the thermoelectric device 6 could be ambient air, or an auxiliary cooling circuit such as an engine charge air cooling circuit or a vehicle cabin air-conditioning circuit.

Said materials preferably have a maximum conversion efficiency between 500°C and 600°C, such as (p-Zn_4Sb_3, n-Mg_2Si) or (p- and n-$CoSb_3$).

The operation of the invention is now described.

When the active regeneration means 4 are not activated, i.e. when no active regeneration is being carried out, the thermoelectric device 6 can produce electricity from the heat flux through the thermoelectric elements between the exhaust gases temperature and the coolant, provided the exhaust gases temperature downstream said thermoelectric device 6 is not lowered too much, which would be harmful to the SCR efficiency

If needed, in order to prevent an excessive decrease of said temperature, the valve 11 can be partially closed to reduce the coolant flow, or even completely closed to reduce the heat flux through the thermoelectric device 6. Alternatively, or additionally, it is envisaged to control the coolant temperature for the same purpose. Alternatively, or additionally, it is envisaged to stop or reduce the electric current generation by the thermoelectric device, simply by opening the electric circuit to which it is connected and/or by reducing the current in that circuit through appropriate control means odd aid electrical circuit. In all cases, this will reduce the amount of heat which is drawn from the exhaust gases.

When the filter 2 becomes clogged, the active regeneration means are activated during a regeneration period, in order to promote the oxidation of the particles retained in said filter 2. As a consequence, the exhaust gases temperature just downstream from the filter 2 is temporarily greatly increased (typically from around 400°C to around 600°C) thanks to the heat provided by the active regeneration means. In order to recover at least part of the energy spend to regenerate the filter 2, the thermoelectric device 6 is used, possibly up to its full capacity, to produce electricity which can then be used for the operation of various elements of the vehicle, and/or can be stored in an energy storage component such as a battery. Thus, the invention makes it possible to

improve the engine arrangement efficiency, which has a direct impact on fuel consumption.

Moreover, the operation of the thermoelectric device 6 leads to a significant decrease in the exhaust gases temperature. This prevents the SCR 3 from being damaged by high temperatures resulting from the regeneration of the filter 2.

Figure 2 shows an example of the evolution of the temperature of the exhaust gases in the flow direction x (see Figure 1) during a regeneration period.

In this example, the exhaust gases temperature upstream from the active regeneration means 4 is around 400°C (this value depends on the engine operating conditions), and suddenly increases up to around 600°C at the active regeneration means location x4.

With an engine arrangement according to the prior art (dotted line), the exhaust gases temperature remains at around 600°C until the SCR inlet (location x3in) and then slightly decreases until the SCR outlet (location x3out). Therefore, there is a risk of damaging the SCR 3 due to too high temperatures.

In contrast, with an engine according to the invention (full line), the exhaust gases temperature remains at around 600°C until the thermoelectric device inlet (location x6in), but then quickly decreases down to around 350°C at the thermoelectric device outlet (location x6out). As a result, in addition to enabling an energy recovery, the invention provides means for protecting the SCR 3.

Of course, the invention is not restricted to the embodiment described above by way of non-limiting example, but on the contrary it encompasses all embodiments thereof.

CLAIMS

1. An internal combustion engine arrangement comprising:

- an exhaust line (1) capable of collecting exhaust gas from the internal combustion engine, said exhaust line including a particulate filter (2);
- active regenerating means (4, 5) located in the exhaust line and capable of generating heat during a regeneration period so as to promote oxidation of the particles retained in said filter (2);

characterized in that said internal combustion engine arrangement further comprises a thermoelectric device (6) capable of producing electricity by Seebeck effect by the conversion of a heat flux between the hot exhaust gases flowing in the exhaust line (1) and a cold source, said thermoelectric device (6) being located downstream from said filter (2).

2. The arrangement according to claim 1, characterized in that the exhaust line (1) includes a further after-treatment device (3), such as a selective catalytic reduction device (SCR), located downstream from said thermoelectric device (6).

3. The arrangement according to claim 1 or claim 2, characterized in that the thermoelectric device (6) comprises thermoelectric elements (7) made of a material or set of materials having a maximum conversion efficiency between 500°C and 700°C, preferably between 500°C and 600°C.

4. The arrangement according to any one of claims 1 to 3, characterized in that the thermoelectric device (6) comprises thermoelectric elements (7) made of at least one material pertaining to the following group: (p-Zn_4Sb_3, n-Mg_2Si), (p- and n-$CoSb_3$).

5. The arrangement according to any one of claims 1 to 4, characterized in that it comprises control means (11, 12) for controlling the flow and/or the temperature of the cold source.

6. The arrangement according to any one of claims 1 to 4, characterized in that it comprises deactivation means (11, 12) for deactivating the thermoelectric device (6) outside of a regeneration period.

7. The arrangement according to any one of claims 1 to 6, characterized in that the cold source is the engine cooling fluid.

8. The arrangement according to any one of claims 1 to 7, characterized in that the cold source is ambient air.

9. The arrangement according to any one of claims 1 to 8, characterized in that said active regenerating means comprise a dedicated fuel burner (4), a dedicated fuel injector, and/or a dedicated electric heater.

10. The arrangement according to any one of claims 1 to 7, characterized in that the thermoelectric device (6) is connected to a battery (13) and / or to one or more vehicular component that are electrically operated.

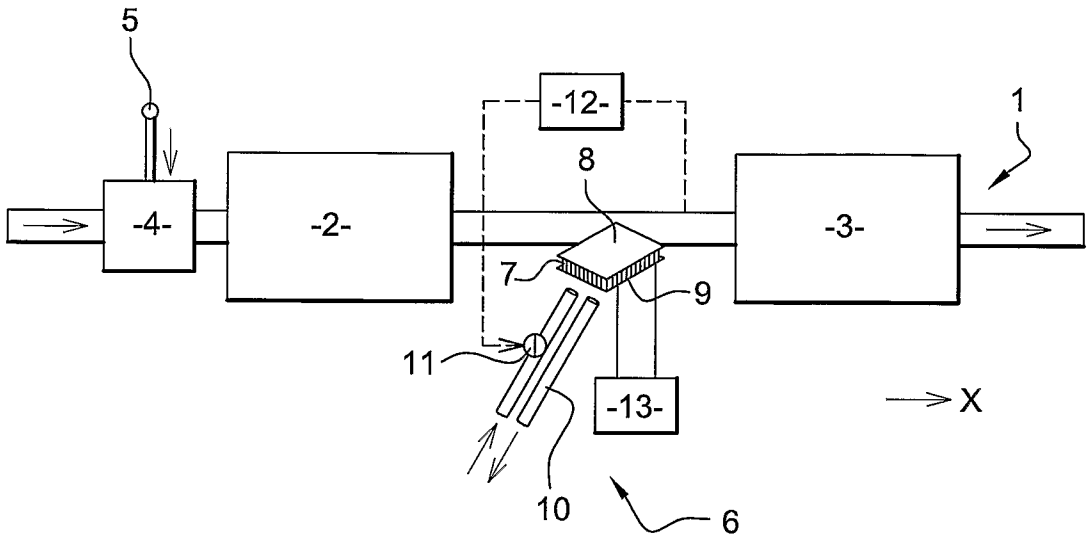
5
-12-
1
8
-4-
-2-
-3-
7
9
11
-13-
X
10
6

Fig. 1

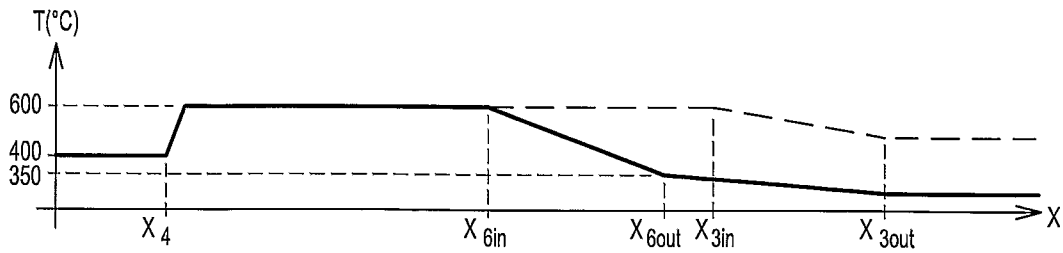
T(°C)
600
400
350
X 4
X 6in
X 6out
X 3in
X 3out
X

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2009/005596

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01N5/02 F01N3/20 H01L35/18 H01L35/22 H01L35/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01N H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	FR 2 918 112 A1 (RENAULT SA) 2 January 2009 (2009-01-02) page 5, lines 18-31; figure 1	1,3-10 2
Y	WO 2009/017639 A1 (CATERPILLAR INC [US]; ROBEL WADE J [US]; CHAVANNAVAR PRAVEEN S [US]; H) 5 February 2009 (2009-02-05) abstract; figure 3	2
A	DE 10 2004 016349 A1 (DAIMLER CHRYSLER AG [DE]) 25 November 2004 (2004-11-25) abstract; figure 2	1
A	US 2005/204733 A1 (SASAKI TOSHITAKE [JP]) 22 September 2005 (2005-09-22) paragraph [0050]; figure 1	1

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 August 2009	01/09/2009

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2009/005596

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1 522 685 A1 (TOYOTA MOTOR CO LTD [JP]) 13 April 2005 (2005-04-13) abstract; figure 1	1
A	JP 06 002539 A (AISIN SEIKI) 11 January 1994 (1994-01-11) figures 2,3	1-10
A	US 2005/268598 A1 (YANG JIHUI [CA] ET AL) 8 December 2005 (2005-12-08) abstract; figure 1	1-10
A	EP 1 500 808 A1 (FORD GLOBAL TECH LLC [US]) 26 January 2005 (2005-01-26) paragraphs [0012], [0013], [0014]; figure 3	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2009/005596

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR 2918112 A1	02-01-2009	NONE	
WO 2009017639 A1	05-02-2009	US 2009035194 A1	05-02-2009
DE 102004016349 A1	25-11-2004	NONE	
US 2005204733 A1	22-09-2005	CN 1673497 A	28-09-2005
		DE 102005013330 A1	20-10-2005
		JP 4085998 B2	14-05-2008
		JP 2005264916 A	29-09-2005
EP 1522685 A1	13-04-2005	CN 1605740 A	13-04-2005
		DE 602004003652 T2	27-09-2007
		JP 4165405 B2	15-10-2008
		JP 2005137188 A	26-05-2005
		US 2005072142 A1	07-04-2005
JP 6002539 A	11-01-1994	NONE	
US 2005268598 A1	08-12-2005	NONE	
EP 1500808 A1	26-01-2005	NONE	